INDOOR AIR QUALITY INVESTIGATION IN A NATURALLY VENTILATED UNIVERSITY BUILDING, AIR CHANGE MEASUREMENT AND CALCULATION CASE STUDY

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ABSTRACT

Indoor environment quality is characterized by thermal comfort, indoor air quality, lighting and many other parameters. According to the last trends of energy savings for building services operation and building envelope insulating, the minimum air change rate is evaluated and calculated. Ventilation system control is usually based on the CO_2 measured concentration. The air change rate is dependent on occupant behaviour. When occupants have just natural ventilation in the room then they are not able to control the air change rate. A pilot study was performed in order to figure out a main environmental pollutant during unoccupied time. This study was performed to identify the main IAQ pollutant which may be used to specify a minimum ventilation rate for office buildings and school buildings. How should ventilation system control work – based on which pollutant? The study continues and develops the Clear–up project carried out at the CTU during years 2008 – 2012. The indoor air quality is analysed and evaluated in an office building of a university based on concentration measurements of chemical pollutants: formaldehyde, carbon dioxide and total volatile organic compounds (TVOC). The office building envelope has been retrofitted recently. The paper is focused on the question how the IAQ in an office is influenced by a natural ventilation rate and by the newly retrofitted facade. This paper is focused on experimental description of investigated pollutants in a naturally ventilated room without occupants. The aim of the paper is to determine the most important pollutant to specify ventilation requirements. The measurement was carried out during a weekend period without occupant presence. The ventilation rate was calculated from measured concentrations of a tracer gas SF_6. The air change was calculated as 0,108 [1/h]. The measured pollutant values are presented in charts. The main results are expressed by percentage frequency of measured concentrations divided by permissible exposure limits (PELs). In order to save energy, infiltration through the building envelope is negligible. The office is not equipped with a ventilation system, which has a negative impact on IAQ in the room. The user's personal belongings can also cause higher pollutants concentration and can cause health problems. The conclusion is to find a way to ventilate a room during unoccupied hours.

Keywords: air change, indoor air quality, IAQ measurement, IAQ evaluation, natural ventilation

INTRODUCTION

According to the last trends of energy savings in building services operation and building envelope insulation, the minimum air change rate is calculated considering heat retention. Ventilation system control is usually based on the CO_2 measured concentration. When there is just natural ventilation in a room, it is not always possible to control the air change rate. The air change rate is dependent on the occupant behavior. This paper is focused on experimental description of the investigated pollutants in a naturally ventilated room during unoccupied hours. The aim of the paper is to determine the most important pollutant to specify ventilation requirements.

IAQ VENTILATION RATE AND MEASUREMENT CASE STUDY

Measurement of pollutants and tracer gas concentrations

The measurement was carried out by Innova 1412 (Innova, Denmark). This device works on the photoacoustic spectroscopy principle. The following gases were selected as IAQ parameters and were measured: formaldehyde, carbon dioxide and TVOC (total volatile organic compounds). (Fig. 1, 2).

Tracer gas selection, dosing and measurement

Tracer gas techniques are typically based on active dosing of tracer gas into the tested zone which is not convenient in occupied dwellings. Another possibility is the use of carbon dioxide as a tracer gas. Unfortunately the office was occupied during the a. m. hours and the CO_2 concentration would be dependent on that. Carbon dioxide is not usually used to measure direct ventilation rate. [1] The tracer gas SF_6 was dosed into the investigated office on Friday in the afternoon hours. The concentration uniformity was provided by the use of mixing fan. The tracer gas concentrations were measured. (Fig. 2) According to the EU directive [2], it is forbidden to sell SF_6 gas to unauthorized users and labs and use it. This measurement was carried out before this directive became effective.

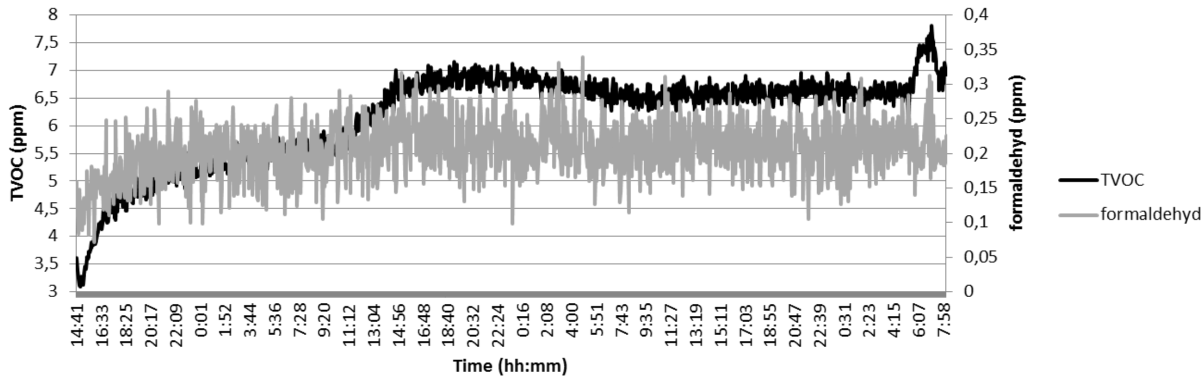

Figure 1: Measured concentrations of formaldehyde and TVOC (total volatile organic compounds).

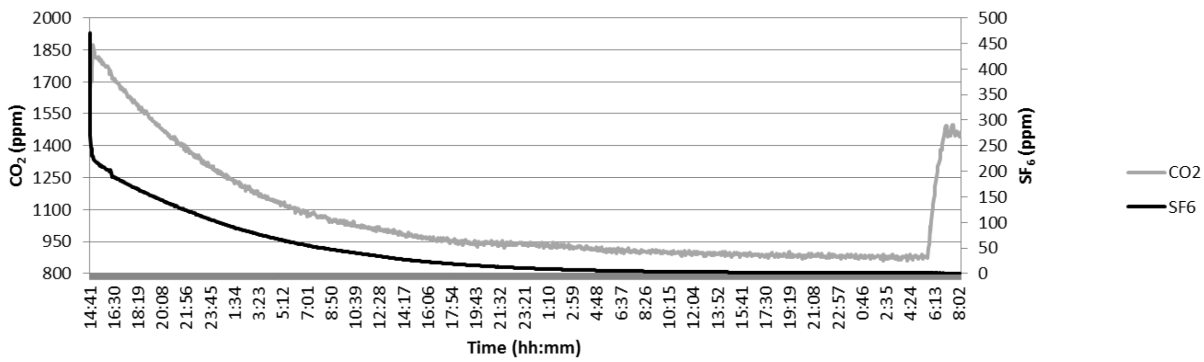

Figure 2: Measured concentrations of carbon dioxide and SF_6 tracer gas.

VENTILATION RATE CALCULATION

The building envelope was recently retrofitted. New air – tight windows were installed together with the thermal insulation. The investigated office is naturally ventilated and the question was if the minimum ventilation rate requirement for unoccupied hours is fulfilled. The required value is according to the standard [3] 0, 1 (1/h). The ventilation rate through the building envelope was calculated by the concentration decay method. This method is one of the so called Age-of-Air methods. According to [4] the used Age-of-Air measurement equation was:

$$AC = \frac{\int_0^\infty C(\tau) d\tau}{C(0)} \left[\frac{1}{h}\right] \tag{1}$$

where

AC	air change rate [1/h]
C (τ)	measured concentration at $\tau = \infty$ [ppm]
C (0)	measured concentration at $\tau = 0$ [ppm]
τ	time of measurement [h]

The air change rate through the envelope was calculated as 0,108 (1/h) which meets the requirements.

IAQ EVALUATION

In the working environment different risk factors may be present, which also include chemical pollutants. In the Czech Republic, the concentration limits of pollutants are mandatorily prescribed in the working environment. [5] The following equation represents how IAQ can be evaluated [6]:

$$\frac{C_{HCHO}}{PEL_{HCHO}} + \frac{C_{CO}}{PEL_{CO}} + \frac{C_{TVOC}}{PEL_{TVOC}} \leq 1 \tag{2}$$

where

C	measured gas concentration [ppm]
PEL	permissible exposure limit [ppm]

The Evaluation of IAQ can vary from country to country. In the following Tab. 1, different PEL and STEL values are given for different averaging times. World Health Organization also has guidelines applicable for Europe. [7], [8]

Table 1: Occupational exposure limits for Germany, Czech Republic and Europe (WHO).

			Czech Gov. Regulation no. 93/2012			
OELs for Germany			**PEL**	**PEL**	**STEL (NPK)**	**STEL (NPK)**
substance	**OEL value mg/m^3**	**Averaging time**	**mg/m^3**	**ppm**	**mg/m^3**	**ppm**
formaldehyde	0.12	Not determined	0.5	0.37	1	0.747
TVOC (total volatile organic compound)	0.2 – 0.3	Not determined	-	-	-	-
WHO Air Quality Guidelines for Europe (2010)	**Guideline values for individual substances**		**PEL**	**PEL**	**STEL (NPK)**	**STEL (NPK)**
substance	**Time – weighted average value mg/m^3**	**Averaging time**	**mg/m^3**	**ppm**	**mg/m^3**	**ppm**
Carbon monoxide	7	24 h	-	-	-	-
Carbon monoxide	10	8 h	30	24	150	120
Carbon monoxide	35	1 h	30	24	150	120
Carbon monoxide	100	15 min	30	24	150	120
formaldehyde	0.1	30 min	0.5	0.37	1	0.747

RESULTS

In the Table 1 there is a comparison of obtained results. The air changes for CO_2, TVOC and formaldehyde were calculated. The air change through the building envelope was higher than the air change to get rid of CO_2 concentration and TVOC concentration. The air change for formaldehyde is a negative value. That means the volume should not be ventilated because of outside concentration is higher than inside concentration.

DISCUSSION

This measurement was taken just for the above mentioned pollutants. Therefore we cannot predict other possible pollutants concentration. The whole measurement was carried out with completely closed windows however modern air-tight windows also have the “micro – ventilation” possibility which would change the air change rate significantly. The measurement was influenced by an unexpected occupant presence before the end of it. Therefore there are peaks for some values in the measurement. In the investigated office there was not a single flower. It would be interesting to solve this problem for the new passive houses standard.

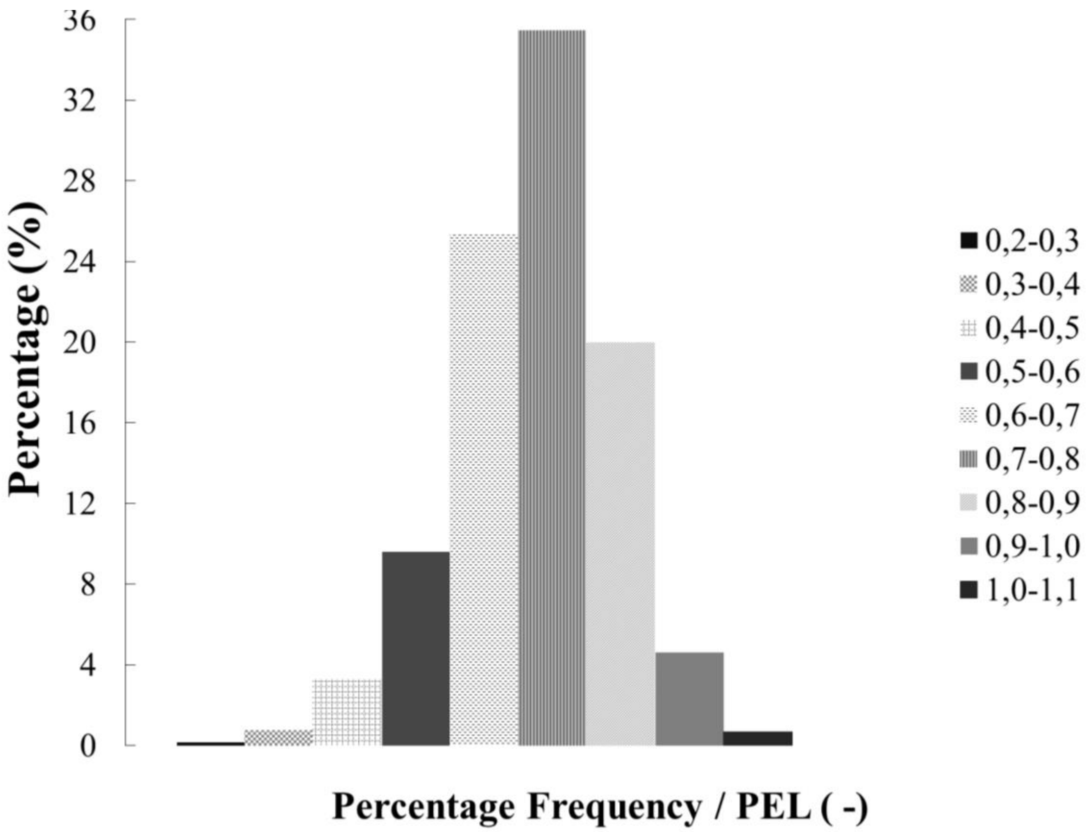

Figure 3: Percentage frequency of values present in the above mentioned ranges.

CONCLUSION

The aim of the experiment was to find a crucial IAQ pollutant for room ventilation without occupant presence. It is a complicated problem with many changing boundary conditions. Which pollutant should be the most important? According to the measurements and calculations the air change was calculated as 0,108 (1/h). The other air changes to ventilate the whole investigated office and get rid of pollutants were: 0,015 1/h (to get rid of the CO_2 concentration), 0,021 (TVOC) and, -0,012 (formaldehyde) which says that the outdoor concentration is higher than the indoor concentration. That brings the dilemma if ventilating is indicated or not. The changing outdoor boundary conditions (location of the building close to highways, city centre during rush hours) are the main deciding factors for ventilation of the office during unoccupied time.

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